CHAPTER 10. NATIONAL IMPACT ANALYSIS

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CHAPTER 10. NATIONAL IMPACT ANALYSIS

10.1 INTRODUCTION

This chapter describes the Department's estimation of the quantity of national energy savings (NES) and the net value to consumers from new furnace and boiler efficiency standards. For specific efficiency levels in each product class, it describes: 1) cumulative NES in the considered period (2012–2035), and 2) the net present value (NPV) of efficiency standards for consumers, accounting for products installed in the considered period. The NPV represents the difference between the present value of operating cost savings and increased installed costs.

Figure 10.2.1 depicts the process and inputs for calculating the above results. The Department performed all calculations using a Microsoft Excel spreadsheet. Section 10.5 discusses access to the spreadsheets.

The Department considered standards independently for each product class, as it does not expect any market effects between the considered product classes as a result of standards. In the Department's analysis, the level of efficiency improvement considered for one product class does not affect the energy or financial impacts of the other classes.

10.2 NATIONAL ENERGY SAVINGS

10.2.1 Definition

The Department calculates annual NES as the difference between two projections: annual energy consumption (AEC) in the base case forecast (without new standards), and AEC in a case with new standards. Positive values of NES correspond to energy savings (i.e., national energy consumption with standards is less than national energy consumption in the base case forecast).

$$NES_y = AEC_{base} - AEC_{standard}$$

Cumulative energy savings are the sum over a defined time period (2012 to 2035) of the annual national energy savings:

$$NES_{cum} = \sum NES_y$$

The Department calculates the national annual energy consumption in each product class by multiplying the number of existing furnaces or boilers (by vintage) by the unit energy consumption (UEC) (also by vintage), as represented by the following equation:

$$AEC = \sum STOCK_V \cdot UEC_V$$

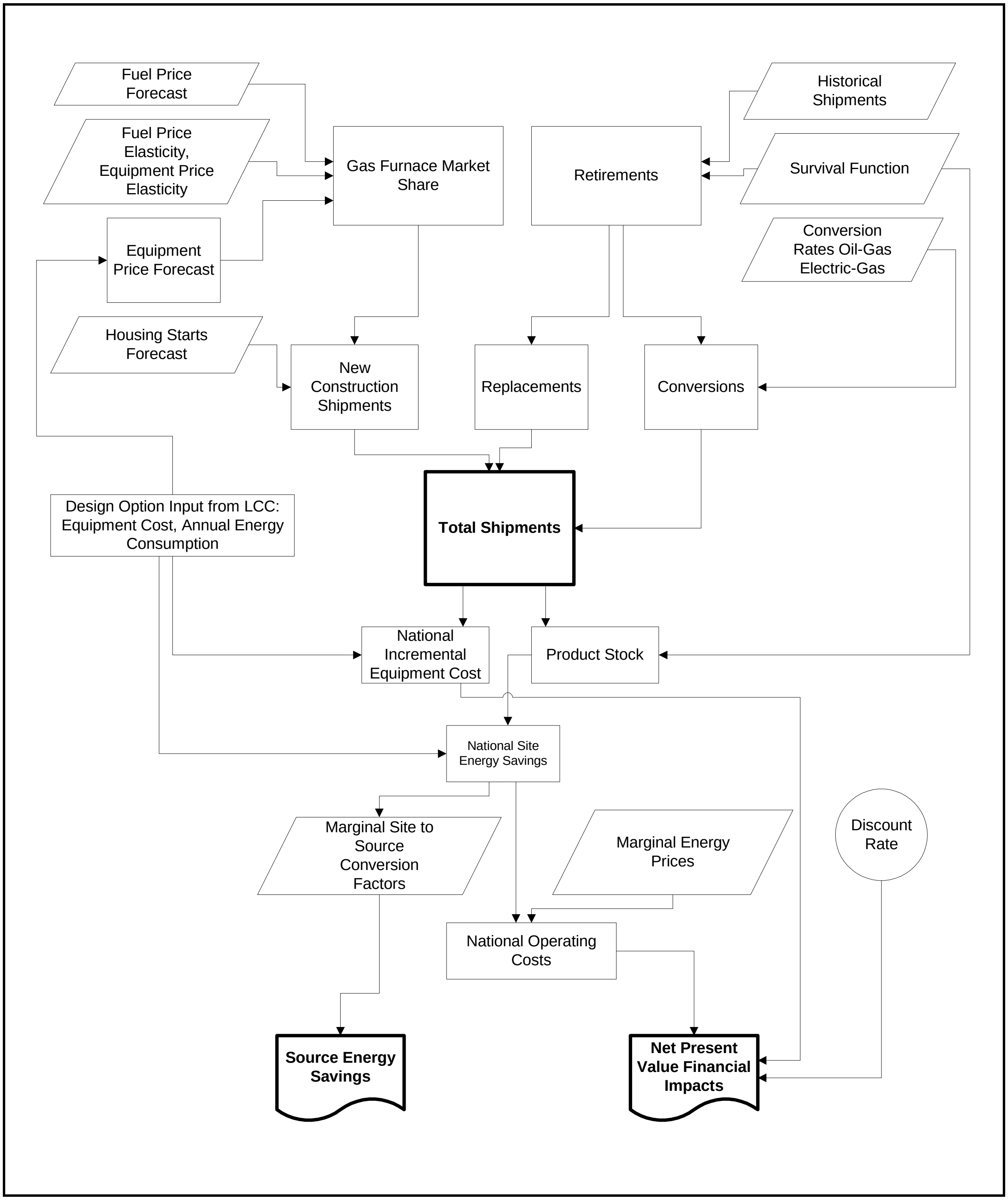

Figure 10.2.1 NES and NPV Process and Inputs

For the above expressions, DOE defines the terms as follows:

NES = annual national energy savings (Quads),
AEC = annual national energy consumption each year (Quads), summed over vintages of the stock, $STOCK_V$,
$STOCK_V$ = stock of furnaces or boilers in use in U.S. homes (millions of units) of vintage *V* surviving in the year for which DOE is calculating annual energy consumption. Vintages range from 1 to approximately 30 years, depending on the lifetime of the equipment,
UEC_V = annual energy consumption per furnace or boiler (million Btu for gas and kWh for electricity). Gas and electricity consumption is converted from site energy (kWh) to source energy (Quads) by applying a time-dependent conversion factor,
V = vintage (year in which a new unit was purchased), and
y = year in the forecast.

The stock of equipment is dependent on annual shipments and the lifetime of the equipment.

10.2.2 National Energy Savings Inputs

This section describes the inputs for the determination of NES.

10.2.2.1 Annual Energy Consumption per Unit

The annual energy consumption per unit (UEC) is the site energy consumed by a furnace or boiler per year. It includes gas (or oil) consumption and electricity consumption. The annual gas or oil consumption is directly related to the efficiency Annual Fuel Utilization Efficiency (AFUE) of the unit. Using the energy consumption calculations described in Chapter 7, DOE determined the national average annual energy consumption that corresponds to each AFUE level. The average annual electricity consumption used in the NES model is the average value from the energy consumption calculations that correspond to each AFUE level.

For non-weatherized gas furnaces, the NES model considers non-condensing and condensing furnaces separately. The average current AFUE (based on data from the Gas Appliance manufacturers Association (GAMA))[1] is approximately 80 percent for non-condensing furnaces and 93 percent for condensing types. There is a limited amount of historical efficiency data available for furnaces, but the evidence suggests that there has been little change since the early 1990s within non-condensing and condensing furnace types. Therefore, the base case forecast assumes that current efficiencies remain constant.

The Department forecasted the share of condensing furnaces based on the average growth rate in 1991–2000 (Table 10.2.1).

Table 10.2.1 Trend of the Market Share of Condensing Furnaces in Total Shipments of Non-Weatherized Gas Furnaces (percent)

Year	Share (%)
1991	20.5*
2000	23.4*
2012	27.4
2020	30.4
2030	34.6

* From GAMA[1]

For other product classes, there is little evidence of change in recent years in the average AFUE. Therefore, DOE used the current average shipment-weighted efficiency of each product class (based on data from GAMA[1]) for the base case forecast (Table 10.2.2).

Table 10.2.2 Base Case Forecast AFUE of Other Product Classes

Product Class	AFUE (%)
Weatherized gas furnaces	80.6
Mobile home gas furnaces	79.8
Oil-fired furnaces	81.1
Gas boilers	81.9
Oil-fired boilers	83.9

10.2.2.2 Shipments

For non-weatherized gas furnaces and mobile home gas furnaces, the Department forecasted shipments for the standards cases as a function of installed costs. In these cases, the increased installed cost of more-efficient gas-fired equipment causes some customers to purchase electric rather than gas equipment. If projected shipments of gas equipment are lower in the higher-efficiency cases, there is an increase in electric heating equipment, for which the model accounts. For non-weatherized gas furnaces, DOE assumes that heat pumps account for 60 percent of the additional electric heating equipment purchased due to new standards, and electric resistance furnaces account for 40 percent (based on equipment shares in homes built in 1995–1999). For mobile home gas furnaces, the assumed shares of additional electric heating equipment purchased due to new standards are 33 percent for heat pumps and 67 percent for electric resistance furnaces.

An extensive description of the methodology for conducting and generating the shipments forecasts can be found in Chapter 9.

10.2.2.3 Equipment Stock

The stock in a given year is the number of units shipped from earlier years that survive (remain in use) in the given year. The NES spreadsheet model keeps track of the number of units shipped each year. The Department assumed that the units have an increasing probability of retiring as they age. The survival function is the probability of survival as a function of years-since-purchase, which is equivalent to the percentage not replaced.

The stock of non-weatherized gas furnaces and mobile home gas furnaces under the standards cases is slightly less than that under the base case forecast, due to the lower number of shipments forecasted for the standards cases. The Department accounted for the accompanying increase in the stock of electric heating equipment.

10.2.2.4 National Annual Energy Consumption

For each product class, the national energy consumption in a given year is the product of the annual energy consumption per unit and the number of units of each vintage. This approach accounts for differences in unit energy consumption from year to year.

For non-weatherized gas furnaces and mobile home gas furnaces, DOE accounted for the energy consumption by electric heating equipment used instead of gas furnaces in the standards cases. For non-weatherized gas furnace standards cases, the annual energy consumption per electric heating unit is based on the average heating energy consumption for RECS97 houses in the South that were heated by gas furnaces and heat pumps.[2] (The Department used houses in the South because most of the projected shift from gas to electric equipment takes place in the South.) For mobile home gas furnaces standards cases, the annual energy consumption per electric heating unit is based on the average heating energy consumption for RECS97 mobile homes that used electric heating.

10.2.2.5 Site-to-Source Conversion Factor

In determining national annual energy consumption, DOE initially calculated the annual energy consumption at the site. The Department then calculated primary (source) energy consumption from site energy consumption by applying a conversion factor to account for losses associated with the generation, transmission, and distribution of electricity and gas. The site-to-source conversion factor is the multiplicative factor used for converting site energy consumption into primary or source energy consumption, expressed in Quads (quadrillion Btu). The Department used annual site-to-source conversion factors based on the Lawrence Berkeley National Laboratory (LBNL) version of the National Energy Modeling System (NEMS), which corresponds to DOE's Energy Information Administration (EIA's) *Annual Energy Outlook 2002* (*AEO2002*).[3] The factors used are marginal values, which represent the response of the system to an incremental decrease in consumption. Natural gas losses include pipeline leakage, pumping energy, and transportation fuel. The *AEO2002* forecasts losses of about 7 percent for the natural gas used on site, with only slight variation from year to year. For electricity, the conversion factors vary over time, due to projected changes in generation sources (i.e., the power plant types projected to provide electricity to the country). The Department assumed that conversion factors remain constant at 2020 values throughout the remainder of the forecast. The Department assumed no losses for delivery of site heating oil.

10.2.2.6 Summary of Inputs

Table 10.2.3 summarizes the inputs to the NES model.

Table 10.2.3 NES and NPV Inputs

Parameter	Data Description
Shipments	Annual values from shipments model (see Chapter 9)
Effective Date of Standard	2012
Base Case Forecast Efficiencies	Current market-weighted AFUE from GAMA data
Standards Case Efficiencies	Established from the Life-Cycle Cost Analysis, Chapter 8
Annual Energy Consumption per Unit	Annual weighted-average values are a function of efficiency level (established from the Energy Consumption Analysis, Chapter 7)
Total Installed Cost per Unit	Annual values are a function of efficiency level (established from the Life-Cycle Cost Analysis, Chapter 8)
Energy Expense per Unit	Annual values are a function of the annual energy consumption and energy prices (established from the Life-Cycle Cost Analysis, Chapter 8)
Maintenance Cost per Unit	Established from the Life-Cycle Cost Analysis, Chapter 8
Energy Prices	*AEO2003* forecasts through 2025; extrapolation beyond 2025
Energy Site-to-Source Conversion	Marginal annual values through 2020 are from NEMS; varies yearly for electricity to account for trends in generation mix
Discount Rate	7% and 3% real
Present Year	Future monetary values are discounted to year 2001

10.3 CONSUMER IMPACTS: NET PRESENT VALUE

10.3.1 Definition

Net present value is the value in the present time of a time series of costs and savings. The NPV is described by the equation:

$$NPV = PVS - PVC$$

where:

PVS = present value of operating cost savings (including energy and maintenance costs), and
PVC = present value of increased installed costs (including equipment and installation).

PVS and *PVC* are determined according to the following expressions:

$$PVS = \sum OCS_y \cdot DF_y$$

$$PVC = \sum TIC_y \cdot DF_y$$

where:

OCS = total annual operating cost savings,
TIC = total annual installed cost increases,
DF = discount factor, and
y = year for which *PVS* and *PVC* are determined.

The Department determined *PVC* for each year from the effective date of the standard to 2035. It calculated *PVS* for each year from the effective date of the standard to the last year when units purchased in 2035 are retired.

The Department calculated the NPV from the projections of national expenditures for furnaces and boilers, including total installed cost and operating costs. The Department calculated costs and savings as the difference between a standards case forecast and a base case forecast (i.e., without new standards).

The Department calculated a discount factor from the discount rate and the number of years between the “present” (i.e., year to which the sum is being discounted) and the year in which the costs and savings occur. The net present value is the sum over time of the discounted net savings.

10.3.2 Net Present Value Inputs

This section describes the inputs to the NPV calculation.

10.3.2.1 Total Annual Installed Cost

The average installed cost for the base case forecast and each efficiency level in 2012 comes from the life-cycle cost (LCC) analysis (see Chapter 8). Because of the uncertainty concerning future trends in furnace and boiler manufacturing, DOE assumed no change in average real equipment costs at each efficiency level after 2012. The increase in the total annual installed cost is equal to the difference in the per-unit total installed cost between base case forecast and standards forecast multiplied by the shipments forecasted in a standards case.

The total incremental cost of equipment between a standards case forecast and the base case forecast depends on the average incremental cost of each unit, and on any changes in shipments. For non-weatherized gas furnaces and mobile home gas furnaces, DOE accounted for the cost of electric equipment that would be used in new homes instead of a gas furnace and air conditioner package in the standards cases. For non-weatherized gas furnaces, DOE compared the estimated cost of a typical gas furnace/air conditioner package ($4072) with the weighted-average cost of a heat pump (60 percent weight) and an electric resistance furnace/air conditioner package: ($3333).[a] Thus, using an electric heating/cooling combination instead of a gas furnace and air conditioner package yields a savings in installed cost of $4072-3333 = $739.

For mobile home gas furnaces, DOE used a similar approach as described above. The Department modified the above costs of electric heating and cooling equipment to account for the smaller size of the equipment used in mobile homes. In this case, the heat pump received a lower weight, since heat pumps are less common in mobile homes.

10.3.2.2 Total Annual Operating Cost Savings

The annual operating cost savings to consumers are equal to the difference between base case forecast and standards case forecast, multiplied by the shipments forecasted in a standards case. For non-weatherized gas furnaces and mobile home gas furnaces, DOE accounted for the operating cost of additional electric heating equipment purchased instead of gas-fired equipment in standards cases.

The savings calculation uses the marginal price for gas and electricity, which represents the cost of the last unit of energy used, and the savings on a consumer's energy bill from

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[a] A heat pump receives a 60 percent weight, reflecting its share in new homes with electric central heating. The installed cost of the heat pump is $3668, while the installed cost of the electric furnace/central air conditioner package (40 percent weight) is $2836.

consuming one fewer unit of energy. For oil, the calculation uses the average price, since data to estimate the marginal price were not available.

The Department determined 1998 energy prices for Residential Energy Consumption Survey (RECS) households in the LCC analysis. To project prices out to 2025, DOE used projections of average residential energy prices from *AEO2003*.[4] The Department applied the ratio of the mean marginal energy price to the mean average energy price for the RECS households to the average gas and electricity prices from *AEO2003*. For the years after 2025, DOE applied the average annual growth rate in 2010–2025 for gas and heating oil prices and the average annual growth rate in 2015–2025 for electricity prices.

10.3.2.3 Discount Factor

The discount factor is the factor by which monetary values in one year are multiplied in order to determine the present value. The discount factor (*DF*) is described by the equation:

$$DF = \frac{1}{(1+r)^{(y-y_P)}}$$

where:

r	=	discount rate,
y	=	year of the monetary value, and
y_P	=	year in which the present value is being determined.

The Department used both a 3 percent and a 7 percent real discount rate in accordance with the Office of Management and Budget's (OMB) guidelines.[b]

The Department defines the present year to be 2001, for consistency with the year in which the manufacturer cost data were collected.

10.3.3 Present Value of Costs

The present value of increased total installed costs is the annual difference between a standards case forecast and the base case forecast, discounted to the present and summed for the considered time period.

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[b] Source : Office of Management and Budget's (OMB) guidelines contained in *Circular A-4, Regulatory Analysis*, September 17, 2003.

10.3.4 Present Value of Savings

Total annual operating cost savings is the savings per unit multiplied by the number of units of each vintage surviving in a particular year. The present value of operating cost savings is the annual difference between the base case forecast and standards case forecast, discounted to the present and summed.

10.3.5 Annual Costs and Savings

To illustrate the basic inputs to the NPV calculations, Figure 10.3.1 presents the non-discounted annual installed cost increases and annual operating cost savings at the national level for the 81 percent AFUE non-weatherized gas furnace (single-stage). The figure also shows the net savings, which is the difference between the savings and costs for each year. The annual equipment cost is the increase in equipment price for products purchased each year over the period 2012–2035. The annual operating cost savings is the savings in operating costs for products operating in each year. The NPV is the difference between the cumulative annual discounted savings and the cumulative annual discounted costs.

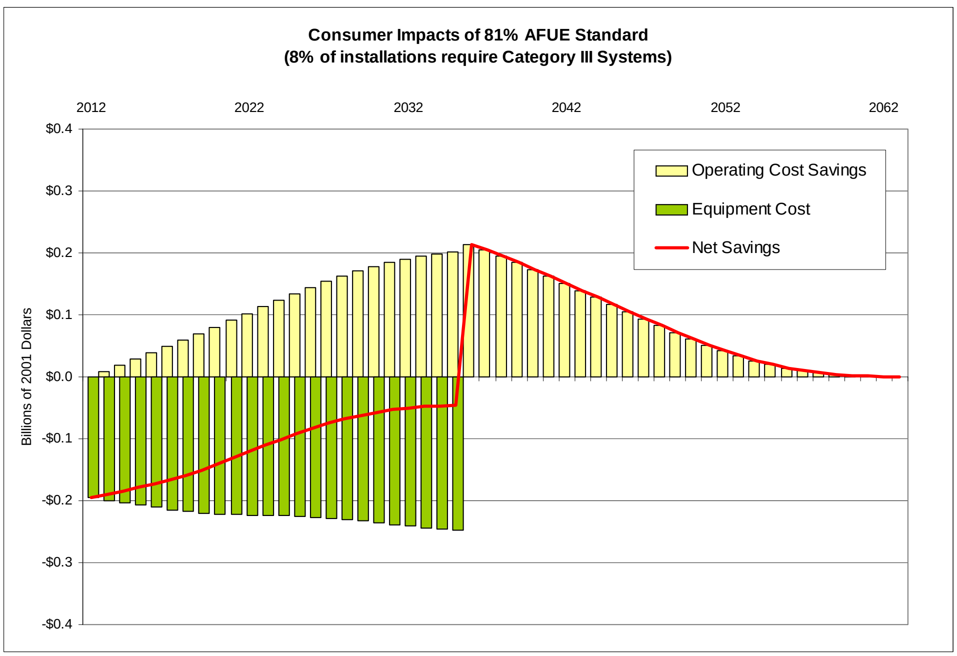

Figure 10.3.1 Non-discounted Annual Installed Cost Increases and Annual Operating Cost Savings at the National Level for the 81 percent AFUE Non-Weatherized Gas Furnace

10.4 NES AND NPV RESULTS

This section provides NES and NPV results for the efficiency levels considered for each product class. The NES spreadsheet model offers a range of possible outputs, all of which depend on the inputs used in deriving the results. The results using the default inputs are presented in the sections below. Appendix 10.1 presents NES/NPV results using alternative inputs for installation cost (for non-weatherized gas furnaces and gas boilers), and energy prices (for all product classes).

10.4.1 Results Using Seven Percent Discount Rate

Table 10.4.1 shows the NES and NPV results for non-weatherized gas furnaces using the Installation Model cost data. The results using Gas Research Institute (GRI) and Natural Resources Canada (NRCan) cost sensitivity data are given in Appendix 10.1. For 81 percent AFUE, results are presented for two cases which represent the most- and least cost-effective cases at this efficiency level. The first assumes a two-stage modulating furnace that does not require Category III venting systems. The second assumes a single-stage furnace that requires Category III venting system in 8 percent of installations.

For non-weatherized gas furnaces, the 80 percent AFUE efficiency level shows very small energy savings and NPV. The 81 percent AFUE efficiency level using two-stage modulation (based on current DOE test procedure as discussed in Appendix 6.3) has energy savings of 1.17 quad, and NPV of $0.87 billion. The 81 percent AFUE efficiency level for the single-stage furnace has energy savings of 0.44 quad, but it has a negative NPV. The condensing furnace efficiency levels (90 percent+ AFUE) have substantial energy savings, but have negative NPV.

Table 10.4.1 Cumulative National Energy Savings and Consumer Net Present Value for Non-Weatherized Gas Furnaces Using 7% Discount Rate

Efficiency Level (AFUE)	NES (Quads)	NPV (billion 2001 $)
80%	0.03	0.05
81%, 2-stage mod., no Cat. III	1.12	0.75
81%, single-stage, 8% Cat. III	0.44	-0.29
82%	0.82	-2.03
90%	4.10	-0.56
92%	4.83	-1.66
96%	7.16	-11.59

Tables 10.4.2 through 10.4.6 show the results for other product classes.

For weatherized gas furnaces, all of the efficiency levels have low but positive NES and NPV quantities.

For mobile home gas furnaces, all of the non-condensing efficiency levels have very low but positive NES and NPV quantities, except for the 82 percent AFUE level, which has slightly negative NPV. For this product class, a shift from gas to electric furnaces due to higher equipment prices associated with higher efficiency has a negative effect on primary energy savings.

For oil-fired furnaces, all of the efficiency levels have low but positive NES and NPV quantities, except for the 84 percent and 85 percent AFUE levels, which have negative NPV.

For hot water gas boilers, the 83 percent AFUE level has NES of 0.24 quad with a positive NPV. For the 88 percent and 99 percent AFUE levels, the NES is positive but the NPV is negative. Results using GRI installation costs are given in Appendix 10.1.

For hot-water oil-fired boilers, the NES and NPV are very low but positive for the 80-84 percent AFUE levels. For the 86 percent and 90 percent AFUE levels, the NES is positive but the NPV is negative.

Table 10.4.2 Cumulative National Energy Savings and Consumer Net Present Value for Weatherized Gas Furnaces Using 7% Discount Rate

Efficiency Level (AFUE)	NES (Quads)	NPV (billion 2001 $)
80%	0.01	0.02
81%	0.08	0.07
82%	0.18	0.14

Table 10.4.3 Cumulative National Energy Savings and Consumer Net Present Value for Mobile Home Gas Furnaces Using 7% Discount Rate

Efficiency Level (AFUE)	NES (Quads)	NPV (billion 2001 $)
80%	0.01	0.01
81%	0.02	0.01
82%	0.02	-0.01
90%	-0.09	-0.38

Table 10.4.4 Cumulative National Energy Savings and Consumer Net Present Value for Non-Weatherized Oil-Fired Furnaces Using 7% Discount Rate

Efficiency Level (AFUE)	NES (Quads)	NPV (billion 2001 $)
80%	0.005	0.01
81%	0.02	0.04
82%	0.04	0.07
83%	0.05	0.11
84%	0.07	-0.15
85%	0.09	-0.11

Table 10.4.5 Cumulative National Energy Savings and Consumer Net Present Value for Hot Water Gas Boilers Using 7% Discount Rate

Efficiency Level (AFUE)	NES (Quads)	NPV (billion 2001 $)
80%	0.03	0.02
81%	0.09	0.10
82%	0.16	0.20
83%	0.24	0.33
88%	0.57	-0.65
99%	1.43	-1.00

Table 10.4.6 Cumulative National Energy Savings and Consumer Net Present Value for Oil-Fired Boilers Using 7% Discount Rate

Efficiency Level (AFUE)	NES (Quads)	NPV (billion 2001 $)
81%	0.003	0.007
82%	0.01	0.02
83%	0.02	0.03
84%	0.03	0.07
86%	0.09	-0.28
90%	0.25	-0.53

10.4.2 Results Using Three Percent Discount Rate

As mentioned above, to estimate the national impacts the Department used also a three percent discount rate. Tables 10.4.7 through 10.4.12 provide the cumulative NPV results based on the three percent discount rate. The NES results are not affected by using a different discount rate.

Using a lower discount rate increases the present value of future costs and savings. In most cases, the result is a more favorable NPV than found using a seven percent discount rate. For efficiency levels that have a very negative LCC impact, however, using a three percent discount rate makes the NPV less favorable (see, e.g., the 82 percent AFUE non-weatherized gas furnace).

Table 10.4.7 Cumulative Consumer Net Present Value for Non-Weatherized Gas Furnaces Using 3% Discount Rate

Efficiency Level (AFUE)	NES (Quads)	NPV (billion 2001 $) using 3%
80%	0.03	0.15
81%, 2-stage mod., no Cat. III	1.12	3.22
81%, single-stage, 8% Cat. III	0.44	0.06
82%	0.82	-3.08
90%	4.10	5.11
92%	4.83	3.36
96%	7.16	-14.48

Table 10.4.8 Cumulative Consumer Net Present Value for Weatherized Gas Furnaces Using 3% Discount Rate

Efficiency Level (AFUE)	NES (Quads)	NPV (billion 2001 $) using 3%
80%	0.01	0.05
81%	0.08	0.21
82%	0.18	0.43

Table 10.4.9 Cumulative Consumer Net Present Value for Mobile Home Gas Furnaces Using 3% Discount Rate

Efficiency Level (AFUE)	NES (Quads)	NPV (billion 2001 $) using 3%
80%	0.01	0.05
81%	0.02	0.03
82%	0.02	-0.01
90%	-0.09	-1.00

Table 10.4.10 Cumulative Consumer Net Present Value for Non-Weatherized Oil-fired Furnaces Using 3% Discount Rate

Efficiency Level (AFUE)	NES (Quads)	NPV (billion 2001 $) using 3%
80%	0.005	0.03
81%	0.02	0.10
82%	0.04	0.19
83%	0.05	0.29
84%	0.07	-0.20
85%	0.09	-0.10

Table 10.4.11 Cumulative Consumer Net Present Value for Hot-Water Gas Boilers Using 3% Discount Rate

Efficiency Level (AFUE)	NES (Quads)	NPV (billion 2001 $) using 3%
80%	0.03	0.09
81%	0.09	0.37
82%	0.16	0.70
83%	0.24	1.10
88%	0.57	-0.42
99%	1.43	0.25

Table 10.4.12 Cumulative Consumer Net Present Value for Hot-Water Oil-fired Boilers Using 3% Discount Rate

Efficiency Level (AFUE)	NES (Quads)	NPV (billion 2001 $) using 3%
81%	0.003	0.02
82%	0.01	0.05
83%	0.02	0.10
84%	0.03	0.20
86%	0.09	-0.40
90%	0.25	-0.62

10.5 NES AND NPV SPREADSHEET

It is possible to examine and reproduce the detailed results obtained in the NES and NPV analysis using a Microsoft Excel spreadsheet available on the U.S. Department of Energy Office of Building Technologies website at: http://www.eren.doe.gov/buildings/codes_standards/.

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